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Case study for a wired versus wireless city network in Ghent

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Abstract

Local communities and governments from all over the world can more and more be considered as drivers for the rollout of new broadband networks relying on future-proof solutions as Fibre to the Home (FTTH) or WiMAX. Numerous examples show the positive impact of these initiatives, and they often stimulate the traditional telecom operator to wait no longer to invest in these new technologies. We have studied the impact of a similar network in Ghent, the third largest city in Belgium. Wired (FTTH) and wireless (WiMAX) alternatives are compared. Several rollout schemes and business models are evaluated and a combined FTTH/WiMAX scenario is proposed in the best interest of the city.

Introduction

In Europe, more than 66% of the current Fibre to the Home (FTTH) investments is driven by local initiatives from municipalities, power utilities and housing companies that want to boost the image of their own community [1]. The network infrastructure in this case is built by diverse new players, taking over the role of the existing telecom operators as infrastructure owner and operator. A similar trend is noticeable in case of wireless broadband networks, where current hotspots are extended to cover larger areas or even a whole city by a WiFi or WiMAX network [2][3].

In this paper, we consider an FTTH and WiMAX rollout by a local community. Section 2 gives an overview of the developed methodology to formulate a complete business model for this kind of networks. Section 3 highlights some important differences in the rollout of both FTTH and WiMAX, and also indicates their typical application areas. The general positive impacts of such a new network on the community are addressed in section 4. A concrete case study for a community network, rolled out by the City of Ghent, is elaborated in section 5. An FTTH and a WiMAX rollout as well as a combined scenario is discussed in the best interest of the city. Section 6 concludes this paper.

Business Modelling Methodology

Fig. 1 illustrates the methodology we used for creating the business model presented in this paper. Starting point is the gathering of geographic, demographic, economic and legal information for the case study. In the case of Ghent we started from a situation in which no telecom infrastructure was available and the only infrastructure which could be reused consisted of housing and reuse of existing ducts (or trenching).

It is not possible to roll out the new network infrastructure throughout a whole city at once (especially in case of FTTH). Therefore we divide the city in different rollout regions. These regions also reflect a logical clustering of residential, business or mixed clients.

As soon as the rollout scheme is determined, we can calculate the number of users. This affects the investments in new infrastructure e.g. the proportion of pre-connections for FTTH vs the number of homes passed. Capital expenses (the long term costs which can be depreciated) as well as operational expenses (the yearly returning costs) are calculated, based on new (digging costs, fibre, etc) and current infrastructure (leased dark fibre, usage of ducts, etc). On the other hand, revenues can be defined. Indirect revenues are generated as a result of effects such as increases in taxes or more investments by firms in the region as opposed to direct revenues that are related to network subscriptions. When all costs and revenues are brought together, the project can be evaluated.

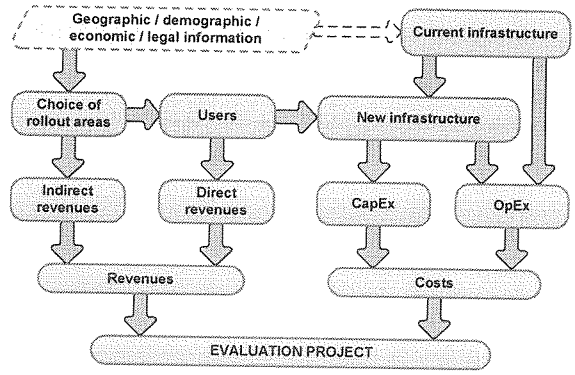

Fig. 1 Business modelling methodology

Technical model for FTTH and WiMAX

A. Fibre to the Home (FTTH)

Within an FTTH network a fibre connection runs from the user to the Central Office (CO), offering a bandwidth up to 1Gbps and even more in the future. Fibre is, due to this high bandwidth, typically considered as the most future-proof fixed-line access network.

There are two main FTTH architectures between the CO and the user. Active architectures offer a dedicated fibre from each user to the Central Office (CO) or a street cabinet, and are Point-to-Point (P2P) networks. Passive Optical Networks (PON) on the other hand are Point-to-Multipoint networks (P2MP), where the access fibre is typically shared by 16 to 64 users. This will reduce the equipment and fibre cost as well as the dedicated bandwidth per user. It might also pose extra restrictions on future upgrades of the network.

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The Central Office (CO) contains an Optical Line Terminal (OLT) which is, among other things, responsible for packet processing, medium access control, etc. In the CO, the aggregation of the different fibre lines from the users is done and it then connects the users to the different Internet Service Providers (ISPs). Typically, cooling and space requirements will limit the connections within a CO to somewhere between 10,000 and 20,000 users **Error! Reference source not found.**. Often, a comparable restriction is also required to limit the fibre lengths between the user and the CO.

Considering the physical rollout of the network, three different possibilities can be distinguished: trenching, blowing or pulling in existing ducts and an aerial rollout. Although aerial rollout is the least expensive solution, it cannot always be used (e.g. according to Belgian legislation, aerial rollout is mostly prohibited and only in some cases a fibre connection can reuse existing poles). If no installed ducts are available, expensive digging works are required by which the connection to every home is by far the highest cost.

Finally on the user side an Optical Network Unit (ONU) will translate the optical signal to the in-house equipment signal (e.g. UTP, wireless).

B. WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is based on the IEEE 802.16 standards and enables the delivery of last mile wireless broadband access as an alternative to DSL and HFC. Today, two important WiMAX profiles are defined: a Fixed and Mobile version, using respectively the IEEE 802.16-2004 and the IEEE 802.16e-2005 standard. It is expected that mainly Mobile WiMAX will be used in the coming years, since it combines bandwidths comparable with DSL access with mobility.

In this case, the CO contains a WiMAX access controller (WAC), which is, among other things, responsible for mobility, access control and accounting. The WAC makes then the connection to the backbone network of the operator.

Via a backhaul network (e.g. WiMAX or an optical network) the WAC is connected to the base stations which are spread over the covered area. To guarantee a complete coverage, a detailed planning of the base station locations is required, and by preference, placed at a sufficient altitude (20 m or higher e.g. by using pylons from existing mobile networks).

On the user side, customer premises equipment (CPE) has to be installed to capture the wireless signals. A distinction can be made between outdoor (e.g. roof mounted) or indoor (e.g. integrated in a PC) CPE. Simplest installation is obtained by the latter, but this comes at the cost of a degraded network performance.

The highest costs to deploy a WiMAX network originate from the installation of pylons to mount the base stations. Here, site sharing can deliver a considerable cost reduction. Furthermore WiMAX license costs are responsible for another important cost factor. The preferred frequency band for Mobile WiMAX is 2.5 GHz, but also other frequencies such as 3.5 GHz (preferable for Fixed WiMAX) are possible. License free operation is another option, but this will reduce the performance because of a limitation on the permitted transmission power.

C. Overview

Table 1 compares the most important points of difference between a FTTH and WiMAX network.

Table 1: Comparison between WiMAX and FTTH

	FTTH	WiMAX
Technology	Fixed-line	Wireless
Bandwidth	Future-proof (e.g. 1 Gbps)	"DSL bandwidth" (e.g. 3 Mbps)
Main costs	Trenching	Sites + pylons License
Target areas	Industrial areas, highly-populated areas (MDUs)	Tourist centers, public places, hotel areas…

Positive Impact of a Municipality Network

In order to get a profitable business case, at least all costs should be covered by revenues considering a predefined planning horizon. Due to their specific nature, community networks and more in particular municipality networks might have several cost and revenue advantages over private network operators.

Municipality networks can get a significant reduction in several parts of the infrastructure costs:

1. Trenching cost
   a. Combining diverse civil works (such as road-works) with the introduction of ducts or fibre.
   b. Reuse of the existing infrastructure, such as the sewer-system, electricity cabling or public transport wiring poles. Although all considered companies are public, the use of their existing infrastructure by the municipality might still involve bilateral agreements.
2. Wireless installation
   a. Reuse of locations on existing municipal buildings.
   b. Backhauling over existing fibre infrastructure. This would be certainly the case when a joint FTTH & wireless network would be rolled out.
3. Central office
   a. Reuse of existing municipal buildings

Direct revenues are generated by means of subscription fees for the users of the network. As the existence of such high bandwidth (in case of FTTH) or ubiquitous connectivity (in case of wireless) allows several new opportunities for the municipality, its inhabitants and companies located in the municipality, the municipality can also gain a lot of indirect revenues or savings of existing costs. Typically these extra revenues are less tangible. Our approach tries to classify these savings or opportunities according to the different applications, drivers or impact of these revenues. We give an overview of this classification and indicate a possible manner in which such revenues can be monetized or estimated.

According to [5] a large infrastructural project can have following typical impacts on the indirect revenues gained:

1. Internal reallocation (of economical advantages) within the considered project area. The aim of a municipality is typically to reduce inequalities in the city.
2. External reallocation (of economical advantages). In this case economical advantages (such as high-tech companies) from outside the municipality are directed towards the municipality,
3. Gain of efficiency will have a positive impact on the economic welfare within the municipality without having a negative effect outside of the municipality.
4. Overall macro-economic impact. It is very hard to estimate the impact a municipality project will have as effect on income, unemployment, level of education, etc. Some nationwide models exist for modeling this effect [6].

The previous classification shows that, especially in case of a municipality, we should focus on the effects of external reallocation and gain of efficiency. The valuation of internal reallocation and overall macro-economic impact are typically very subjective in nature and very complex to model realistically.

As actual economic studies of indirect effects are out of the scope of this study, within calculations, we have made an estimate of the economic impact by relating it to the values found in [7], [8]. This value is not a up-front revenue of the project, but will depend on the state of the rollout and the adoption. All applications will have a different impact on their part of the indirect revenues. We give a coarse classification of possible applications with an indication of the drivers for their indirect revenues:

1. Municipality
   a. Digital municipality services: Allows a large reduction in costs, increase efficiency of services and allow inhabitants of the municipality to more easily retrieve and change information. We can consider the impact of these advantages to increase linear with the percentage of inhabitants connected to the network.
   b. Research platform: A fully rolled out FTTH or WiMAX network allows public research institutes as well as private companies to develop and test new future applications. This might represent a fixed advantage once the network is rolled out.
2. Companies
   a. Increased possibility of clustering with other companies, in case of a FTTH network. The high bandwidth connectivity provided by an FTTH network allows a company to be more directly and more tightly connected to other facilities of the same company or to other companies. A possible valuation would be based on the number of "meaningful" connections of this company to other companies.
   b. New opportunities for commercial activities. The high bandwidth of FTTH could for instance allow advanced (high bandwidth) eCommerce applications. Wireless networks could allow location based applications, more directed forms of advertisement and more visibility of companies.
   c. As Ghent is one of the tourist cities of Belgium, the impact on their revenues could also be driver. We could expect these revenues to be linear (or less than linear) with the number of tourist making use of the network.
3. Inhabitants
   a. Increased connectivity, and in case of FTTH the bandwidth allows for video-calls and P2P video. An estimation of the value of this for the inhabitants will be depending on the number of "meaningful" connections that can be made with other inhabitants.

This description shows that different parts of the indirect revenues should be modeled in different ways. We can distinguish fixed values, linear (or less than linear) increasing values (coupled to number of users, companies, etc.) and network value (coupled to the number of possible "meaningful" connections). The first ones are fairly straightforward, the network value allows for different interpretations of the "meaningful" connections. According to Metcalfe's law [9] the value of a network is proportional to the square of the number of users (originally in the sense of machines) in the network, later refined to $n \cdot (n-1)/2$. An alternative to this law, more closely representing the economic impact of the number of people reached (instead of machines) was proposed by Odlyzko and Tilly [10] and states that the value of the network is $n \cdot \log(n)$.

Case study in Ghent

Ghent is the third largest city of Belgium with 233,644 inhabitants (July 2006) and an area of 156.2 km^2. The average population density thus amounts 1,496 residents per km^2. 16,519 companies have their businesses in Ghent and several industrial zones are located around the city center. Besides Ghent University, the city harvests several colleges, which account all for over 55,000 students, which makes this city the largest college town in Belgium [11]. Within the case study we used a smaller sub area of 22 km^2 with 222 companies and 90,000 inhabitants.

Because of practical reasons, it will not be possible to roll out FTTH throughout the whole city from the beginning. We made a subdivision of the city in 8 areas as indicated in Table 2. Considering the much faster rollout and smaller capital expenditures of wireless networks it makes less sense to use such subdivision for WiMAX.

Table 2 – FTTH rollout areas

Area	Inhabitants	Companies	Trenching (km)	
			Res.	Ind.
1	11046	-	68.8	-
2	-	47	-	18.0
3	7574	-	46.8	-
4	32318	95	163.0	22.9
5	8598	-	40.0	-
6	7802	30	46.0	8.6
7	22439	-	91.0	-
8	-	50	-	8.5

Rollout of FTTH in Ghent

Currently the existing Belgian operators already offer broadband solutions (mainly DSL or HFC) and the market for FTTH will thus be shared amongst these alternatives. The adoption is forecasted using a combination of a generic adoption model as defined in [12] & [13] and a competition model [14] modeling the competition of different generations of the same product (here broadband access). Three generations, roughly based on bandwidth, are used in our calculations: currently existing solutions (ADSL and DOCSIS 1.1) are used as first generation, VDSL and DOCSIS 2.0/3.0 are used as second generation, and FTTH is used as third generation. Finally, as a full FTTH rollout from year one for the City of Ghent is impossible due to timing and resource constraints, the adoption is slightly adjusted to reflect the effect of delayed introduction in the lower priority regions. An example of such adoption curves is shown in Fig. 2.

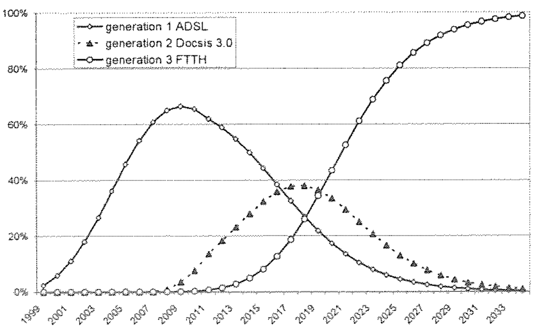

Fig. 2. Adoption of FTTH vs. ADSL and Docsis 3.0

By combining the adoption forecasts with the knowledge of the architecture and the cost evolution of the equipment and workforce [11], [15], [16] & [17], we get an indication of the investment costs for the network. As mentioned before a municipality has the advantage, due to its intrinsic nature, that it can in limited cases combine different civil works, resulting in a reduction of the trenching costs. We consider a 10% possibility of such reductions. Additional reduction in trenching can be obtained by means of aerial rollout. Although such rollout is mostly prohibited by Belgian Legislation, it might be possible to reuse existing poles from public infrastructure.

Main revenues of the network are generated by the customer subscriptions. In calculations the rates of the current competing operators are used. Indirect revenues were modeled using the network valuation model as proposed by Odlyzko and Tilly on all connected users. All cost and revenue figures are combined to calculate the net present value (NPV) of the municipality network, using a discount rate of 10%. Fig. 3 shows the evolution of the NPV for three different rollout speeds. The same figure gives an indication of the difference between a municipality and a private operator, due to the valuation of the positive economic impact and the reduction in trenching. Fig. 4 shows the breakdown of the costs for the considered municipality FTTH rollout, and stresses that trenching takes the largest part of the costs. Fig. 5 shows the evolution of the NPV when the FTTH rollout would be limited to one area with a typical residential or industrial nature.

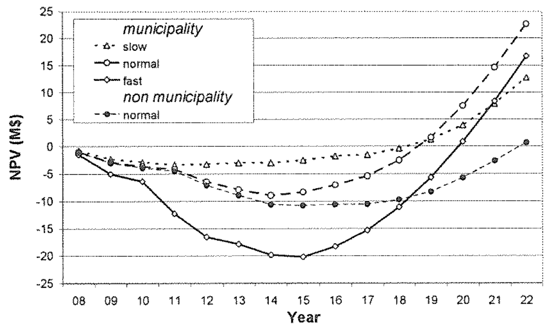

Fig. 3. NPV (FTTH) according to the rollout speed

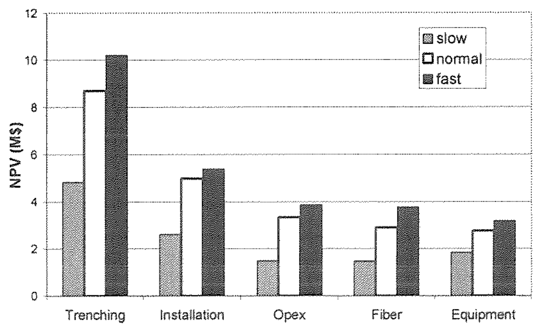

Fig. 4. Breakdown of the FTTH costs

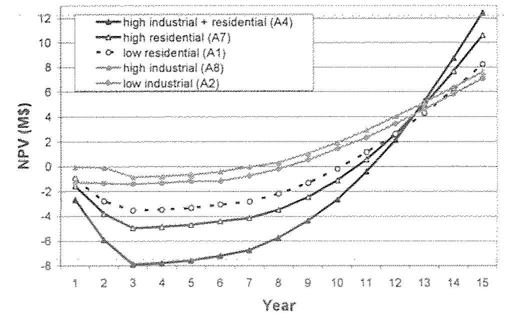

Fig. 5. NPV (FTTH) when rolling out in 1 area

Rollout of wireless network in Ghent

Nowadays, several WiFi hotspots are already available in Ghent, e.g. in the railway station, in many hotels, on some public areas, etc. However, they offer only a local coverage, and mostly, separated payments or subscriptions are required. By offering a wireless city network in Ghent by using Mobile WiMAX, a general service can be offered to a large target group, including the inhabitants themselves, students, tourists, etc. The adoption is also forecasted by using a generic adoption model which is now applied on four different services suited for the diverse target groups. The services are: *Stand alone wireless broadband* (WiMAX used as broadband connection, instead of HFC or DSL, especially suited for the inhabitants), *Second residence* (mainly intended for users that need a second connection, intended for the students), *Nomadicity* (a light version of the previous product, comparable with the current subscriptions to a hotspot, suited for a varying target group) and *Prepaid pack* (a prepaid card grants the user a limited number of hours for using the WiMAX network, which will mainly be used by tourists). The stand alone wireless broadband and second residence service offer a bandwidth of 3 Mbps downstream and 256 kbps upstream, and the other two services have a bandwidth of 512 kbps downstream and 128 kbps upstream. Fig. 6 shows the adoption of the different offered services. We have used absolute numbers, as it is very difficult to use a percentage, as not only the inhabitants of Ghent are taken into account. Note that the prepaid cards are depicted per sold prepaid card of three hours (and not per individual user). Further, we assume a decrease in the take rate of the stand alone service after some years, due to the fact that the foreseen bandwidth will not be sufficient enough as primary broadband connection when triple play services will be offered.

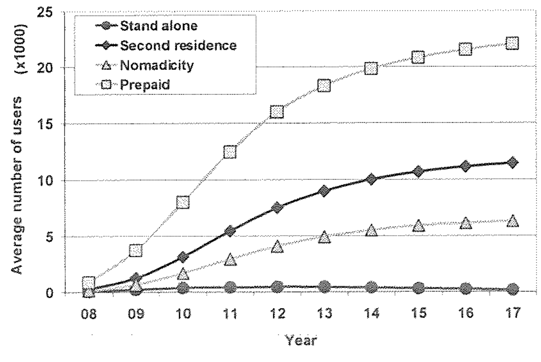

Fig. 6: Adoption of the different WiMAX services

To determine the required investments for the rollout of a WiMAX network, it is essential to properly dimension the network by calculating the required number of base stations and their optimal placing. Bandwidth requirements as well as technical specifications [18] and geographical information is needed as input for a good planning. With the current specifications of Mobile WiMAX, a cell diameter of less than 1 km is required in urban areas. To provide a full coverage in the city of Ghent, minimum 12 base stations are required, with an average height of 30m. To meet the user needs evolving from the adoption curves in Fig. 6, this number increases to 58 in 2017.

Together with the equipment costs (including price evolution) and work force, we again get an indication of the investment costs for the network. As mentioned before a municipality has the advantage, that it can reduce some costs, such as use of locations through the city for the installation of the base stations and the reuse of existing fibres, both owned by the city. For the wireless network, no indirect revenues are taken into account as it is very difficult to make a clear estimation of them, due to the very volatile nature of both connections and subscriptions.

All cost and revenue figures are again combined to calculate the net present value (NPV) of the municipality network, using a discount rate of 15% (which is higher than for the FTTH case, since Mobile WiMAX is a less mature technology today). Fig. 7 shows the evolution of the NPV and gives an indication of the difference between a municipality and a private operator, due to the mentioned cost reductions. Fig. 8 shows the breakdown of the costs for the considered municipality WiMAX rollout, and stresses that base station equipment takes the largest part of the CapEx, but the investments are a lot lower than for a FTTH network. The OpEx on the other hand are somewhat higher, especially by the operational costs of the WiMAX base stations spread over the city, and the high differentiation of offered services which requires extra sales costs.

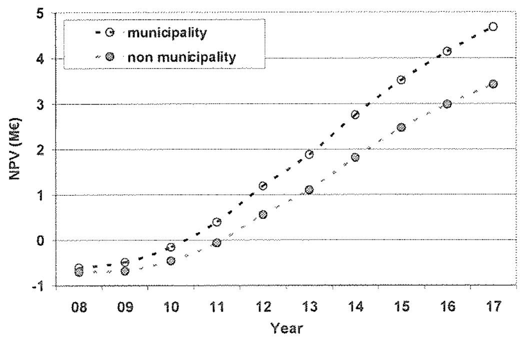

Fig. 7: NPV for the WiMAX network

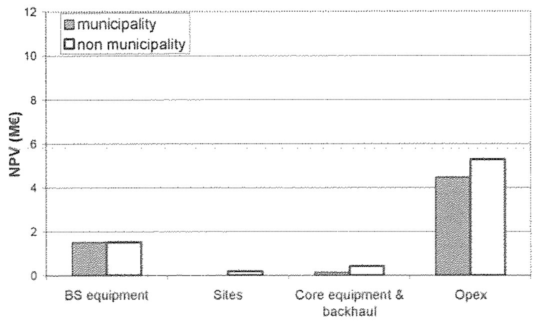

Fig. 8: Breakdown of the WiMAX costs

Conclusions

In the current Belgian situation, the existing telecom operators are reluctant to roll out a new access infrastructure. They see a non-viable business case, or even in case of a viable business case, it is still more profitable to postpone the expenses and exploit the existing infrastructure somewhat longer.

This might be the driver for communities such as municipalities to step in and roll out a new access infrastructure. The first important choice for such infrastructure is whether to roll out a fixed (high bandwidth and future proof) network and/or a wireless (high mobility) network. Both have clearly different advantages and disadvantages, sometimes even opposite. A choice between both will be based on demographic parameters and the envisaged applications.

A case study on the city of Ghent shows that both FTTH and wireless access can provide viable business cases for specific areas. Considering the intrinsic nature of a municipality, the indirect and typically non-economic revenues will have an important impact on the outcome of the business cases. In this paper a classification of these revenues and valuation models for estimating (based on existing examples) or monetizing them are given.

FTTH will be more profitable in highly residential areas, this will for instance be the case when an area contains a high percentage of multi-dwelling units. FTTH infrastructure will also, because of the high bandwidth and the future proof nature, prefer industrial sites. We see that in this case a much smaller infrastructure cost will lead to a high return on investment and a fast payback time.

Wireless will not only be attractive for the inhabitants of the city, but it is also very suited for some specific target groups, such as tourists and students. .So, it will be of utmost importance to provide a good coverage in the city centre and student neighbourhoods. On industrial sites, it is less important as the offered bandwidths are probably too low, and besides most companies have their own wireless network for their visitors.

In this way, a wireless network can be complementary to an FTTH network, which means that for the city of Ghent it might be profitable to roll out both wireless and FTTH in the city centre and close to municipality services outside the city centre. Further FTTH rollout should be focussed on industrial sites and, if still existing outside these areas mentioned before, in highly populated areas. Finally additional wireless access could be provided in these areas which would otherwise not be connected, with a focus on tourist sites. Additionally as rolling out a wireless network involves less manual labour, it can be rolled out more rapidly and could provide connectivity in those regions, pending the rollout of FTTH.

Acknowledgments

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